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I. Factors Concerned in Hemlock Reproduction in Indiana

II. The Ecological Significance of Tsuga Canadensis in Indiana

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BOOK REVIEWS

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STUDIES IN FOREST ECOLOGY

I. Factors Concerned in Hemlock Reproduction in Indiana

By RAY C. FRIESNER AND J. E. POTZGER

INTRODUCTION

Casual observations made during botanical excursions to various parts of the state during the past twelve years have revealed a very scattered and unusual distribution in Indiana of the hemlock, *Tsuga canadensis*. As stated by Deam (4), this species is usually to be found in Indiana on north- or northwest-facing slopes. It is most commonly found on the steep slopes, canyon walls and rims of deep ravines, but may also be found in pure stands in some places such as at Turkey Run, in Parke county, where it is associated with beech and maple on plateau tops above canyon walls, and at Pine Hills, in Montgomery county, where it is associated with beech *(Fagus grandifolia)*, maple *(Acer saccharum* and *A. nigrum)* and white pine *(Pinus strobus)*. In the latter locality the hemlock is usually found on the steep slopes and canyon walls, but occurs in one second terrace groove with white pine, both species occurring with 100 per cent frequency in quadrat studies.

This disjunct distribution, together with the limitation of the hemlock in most of its stations to what appeared to be the most rigorous habitats, raised questions as to just what are the factors involved in hemlock reproduction in Indiana. The present paper is a record of the results of studies made during the year 1930 in an attempt to answer the question of reproductive factors. These studies include observations on seedling establishment as related to character of forest floor, soil moisture, evaporation, soil temperature and seedling mortality which were made at Trevlac, in Brown county, where there is a considerable number of hemlocks along the left (south) bank of Bean Blossom creek.

SEEDLING ESTABLISHMENT AND CHARACTER OF FOREST FLOOR

Thousands of seedlings, one, two and three years old, were to be found with ease. In almost every case seedlings were limited to the slopes or within a few feet back from the rims of the slopes. The most

favorable germination places seemed to be beds of moss, but large numbers were found on free soil where the slope was not too steep to permit lodgment for the seeds, and on the flatter tops up to twenty-five or thirty feet back from the edge of the slope where there were either moss beds or small amounts of broken bits of forest litter. Seedlings were never found where the leaf litter attained any appreciable depth on the forest floor. Seed trees were sufficiently numerous that abundant seeds must have been blown to the plateau-like tops, but it seems from our observations that if the seeds found their way to the soil through the dense leaf litter and secured sufficient moisture, they were unable to lift their growing parts above the too-great depth of leaves and hence had to perish. One cannot escape the conviction as he observes the location of seedlings, that inability to penetrate the deep cover of leaf litter on the forest floor under the dense growth of beech, maple, oak *(Quercus alba, Q. rubra* and *Q. velutina)* and hickory *(Carya cordiformis* and *C. ovata)*, is of prime importance as a factor in hemlock reproduction on the more nearly level plateaus. Seedlings were always limited to those areas where the winds annually blow away the leaves and where there are sufficient mosses or broken forest debris in which the seeds may lodge until germination and establishment occur.

Lutz (6) has shown that in New England shade is a primary factor in establishment of hemlock seedlings. Seedlings came in only where there was shade during at least the hottest part of the day. Our stations were all shaded for at least a part of the day and the stations were so selected with respect to shade that it was eliminated as a factor from our studies. Our observations are in accord with those of Lutz regarding shade, but even when the shade factor is satisfactory we find that character of forest floor is the determining factor. As shown by Lutz (6), Marshall (7) and Frothingham (5), hemlock is able to withstand suppression by hardwoods for long periods of time, but our observations indicate that it does not compete in Indiana with the broad-leaved forest trees except on steep slopes and in occasional groves on plateau tops. Inability of seedling establishment on account of unsuitable forest floor plays a large part in determining this distribution.

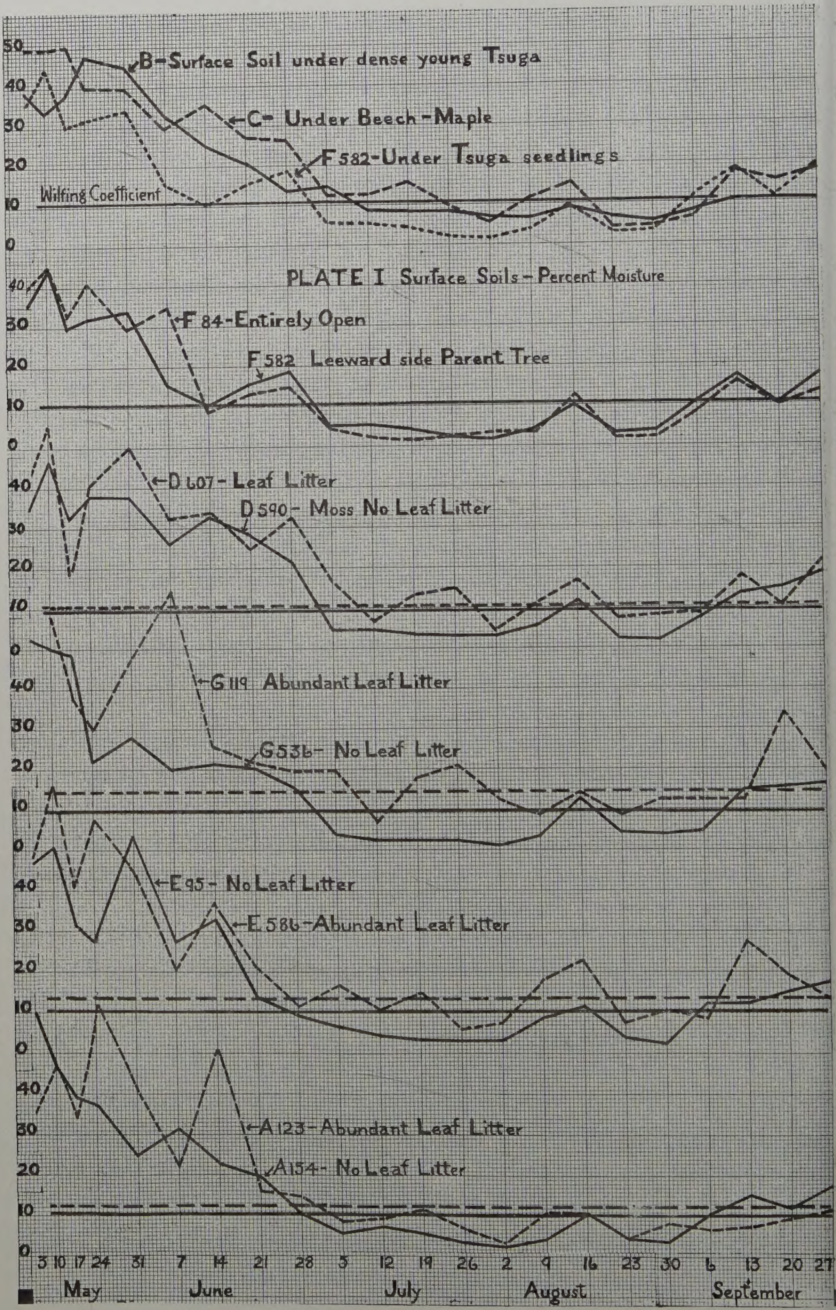
SOIL MOISTURE

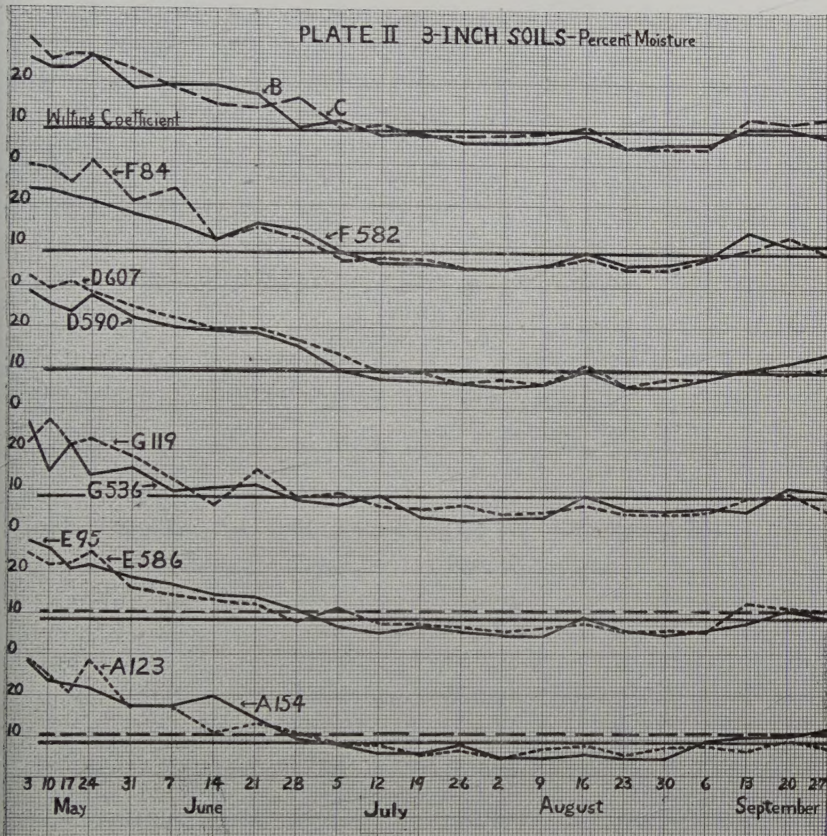
It is a well-known fact that the root system of hemlock is very superficial, and from this one might conclude that available soil moisture should play a very important part in permitting or inhibiting seedling

development. In order to determine whether soil moisture is a controlling factor in determining the particular type of distribution here exhibited, soil was taken weekly from May 3 to September 27, 1930, at twelve different stations, and its moisture content per unit of dry weight was determined. Eight of these stations were so situated that they were but a few feet on either side of the limits of seedling distribution. The seedling limits were very sharp and well marked and coincided in every case with the limits of abundant leaf litter on the forest floor. Seedlings were abundant wherever the wind had sufficient sweep to blow away the leaves. Such places were usually fairly well covered with a carpet of moss. Thus Stations A 154 and A 123 were approximately ten feet apart, each five feet on either side from the line of seedling limits, the former amongst abundant seedlings and the latter where there was a heavy layer of leaves on the floor and no hemlock seedlings were present. Stations D 590 and D 607, E 95 and E 586, and G 536 and G 119 were arranged in similar relationships with respect to the presence and absence of seedlings. Curves of soil moisture content show for almost every week throughout the summer a considerably higher moisture content for the soils covered with leaf litter (and without seedlings) than for soils without leaf litter and having abundant seedlings. This is true for both surface and three-inch soils (Plates I and II).

One is forced to the conclusion, therefore, that character of forest floor is more important in limiting seedling establishment in our stations than moisture content of soil, since seedlings are in every case growing in drier soil and under conditions less favorable in respect to soil moisture than a few feet away where there is more available moisture but no chance to become established.

If Curve B (Plate I), which is drawn from moisture content of soils under a dense stand of hemlock ranging from one to six inches DBH., is compared with curves A 154, E 95, G 536, D 590, F 582 and F 84, all of which are from stations containing hemlock seedlings, it will be noted that for almost every week during the months of July and August the soils in which seedlings were growing were lower in moisture content than the soils about the more mature stand. This is true for surface soils, but less frequently so for three-inch soils (Plate II). Roots of one- and two-year hemlock seedlings rarely if ever penetrate the soil in these stations beyond the first inch, which in turn indicates that


B-Surface Soil under dense young Tsuga
C- Under Beech-Maple
F 582-Under Tsuga seedlings
Wilting Coefficient
PLATE I Surface Soils - Percent Moisture
F 84-Entirely Open
F 582 Leeward side Parent Tree
D 607 - Leaf Litter
D 590 - Moss No Leaf Litter
G 119 Abundant Leaf Litter
G 536 - No Leaf Litter
E 95 - No Leaf Litter
E 586 - Abundant Leaf Litter
A 123 - Abundant Leaf Litter
A 154 - No Leaf Litter
3 10 17 24 31 7 14 21 28 5 12 19 26 2 9 16 23 30 6 13 20 27
May
June
July
August
September



soil factors which influence seedling establishment would necessarily be those in the upper few inches of soil.

When the curves of soil moisture for both surface and three-inch soils (Plates I and II) are studied in reference to the wilting coefficient[1], it is found that the moisture content for every station at which hemlock seedlings were growing (Curves A 154, E 95, G 536, D 590, F 84 and F 582) is below the wilting coefficient for the entire months of July and August, except Curves G 536 and D 590 for the week of August 16. When a similar study is made of curves from stations covered with forest litter and containing no hemlock seedlings, but in each case near the corresponding stations with seedlings (*i. e.*, Curves A 123, E 586,

[1]Wilting coefficient was determined by the formula W.C. $= \frac{\text{ME}}{1.84}$

G 119 and D 607), it will be noted that the soil moisture does not nearly so often fall below the wilting coefficient during these two months.

The wilting coefficients of the soils of the different stations are presented in Table I, where it will be noted that in almost every instance the W. C. of surface soils is higher than that of three- and six-inch soils. This is undoubtedly related to the higher humus content of the surface soil at these stations. The soils three and six inches deep are especially devoid of humus.

TABLE I

WILTING COEFFICIENT OF SOILS AT EACH STATION. EACH VALUE REPRESENTS THE AVERAGE OF SOILS TAKEN DURING NINE DIFFERENT COLLECTINGS AT EACH STATION

Station	Surface Soil	3-inch Soil	6-Inch Soil
A 154	10.245	8.630	8.370
A 123	12.100	10.299	9.751
B	10.883	8.963	9.009
C	10.277	8.312	8.283
D 590	9.537	9.542	8.987
D 607	10.720	9.612	10.401
E 95	10.670	8.945	8.936
E 586	13.850	10.293	10.116
F 582	10.450	8.689	8.214
F 84	10.474	8.996	8.131
G 536	9.890	8.658	7.116
G 119	14.660	8.415	8.366

It will be noted that in every case (Table I: A 154, D 590, E 95 and G 536, compared respectively with A 123, D 607, E 586 and G 119), stations where hemlock seedlings are growing have a lower wilting coefficient than the nearby stations where leaf litter has inhibited seedling establishment. This is undoubtedly related to the lower humus content in areas where the seedlings are growing.

A comparison was also made between soils under more fully developed stands of hemlock and under beech-maple. Curves for Stations B (under dense stand of hemlock and on north-facing slope) and C (under beech-maple with admixture of gum *(Nyssa sylvatica)* and hickory and on south-facing slope) show that the soil is drier for fourteen of the twenty-two weeks under hemlock than under beech-maple, in spite

of the fact that the physiographic features favored the soil of the hemlock station from the standpoint of moisture retention. It thus appears that hemlock stands are more xerophytic in respect to soil moisture than the broad-leaved forest types here present. Daubenmire (3) found the same conditions to exist in comparing hemlock and beech-maple at Turkey Run.

EVAPORATION

Evaporation studies were carried on by use of the Livingston porous clay atmometers. When stations A 154 and A 123 (Plate III), and D 590 and D 607 are compared, there is seen to be a slightly greater average weekly loss where seedlings are growing than where abundant leaf litter has prevented seedling establishment. But when stations E 95 and E 586 are compared, there is a greater average weekly evaporation where seedlings have been inhibited than where they are present.

Comparison of Stations B and C (Plate III) indicate a considerably higher average weekly evaporation in the hemlock stands than in the apparently more open beech-maple. Daubenmire (3) found that there was little difference between hemlock and beech-maple associations in respect to water evaporation at Turkey Run. Our results at Trevlac indicate a more xerophytic condition for hemlock. It should be noted that the hemlock stands studied by Daubenmire were much more mature than those under study at Trevlac and that the season during which our data were taken was unusually dry. A few comparative figures will suffice to bring out the marked difference:

Average Weekly Evaporation

Beech-Maple at Trevlac, 1930	80.9 cc
Beech-Maple at Turkey Run (3), 1929	50.4 cc
Beech-Maple at Sycamore Creek (2), 1929	56.7 cc
Beech-Maple at Sycamore Creek (1), 1928	46.3 cc
Hemlock at Turkey Run (3), 1929	52.2 cc
Hemlock at Trevlac, 1930	90.3 cc

SOIL TEMPERATURES

Soil temperatures taken three inches below soil surface and compared with air temperatures thirty-six inches above the surface showed an average from 0.2 to 1.5° F. greater difference between soil and air temperatures where leaf litter inhibited seedling establishment than where

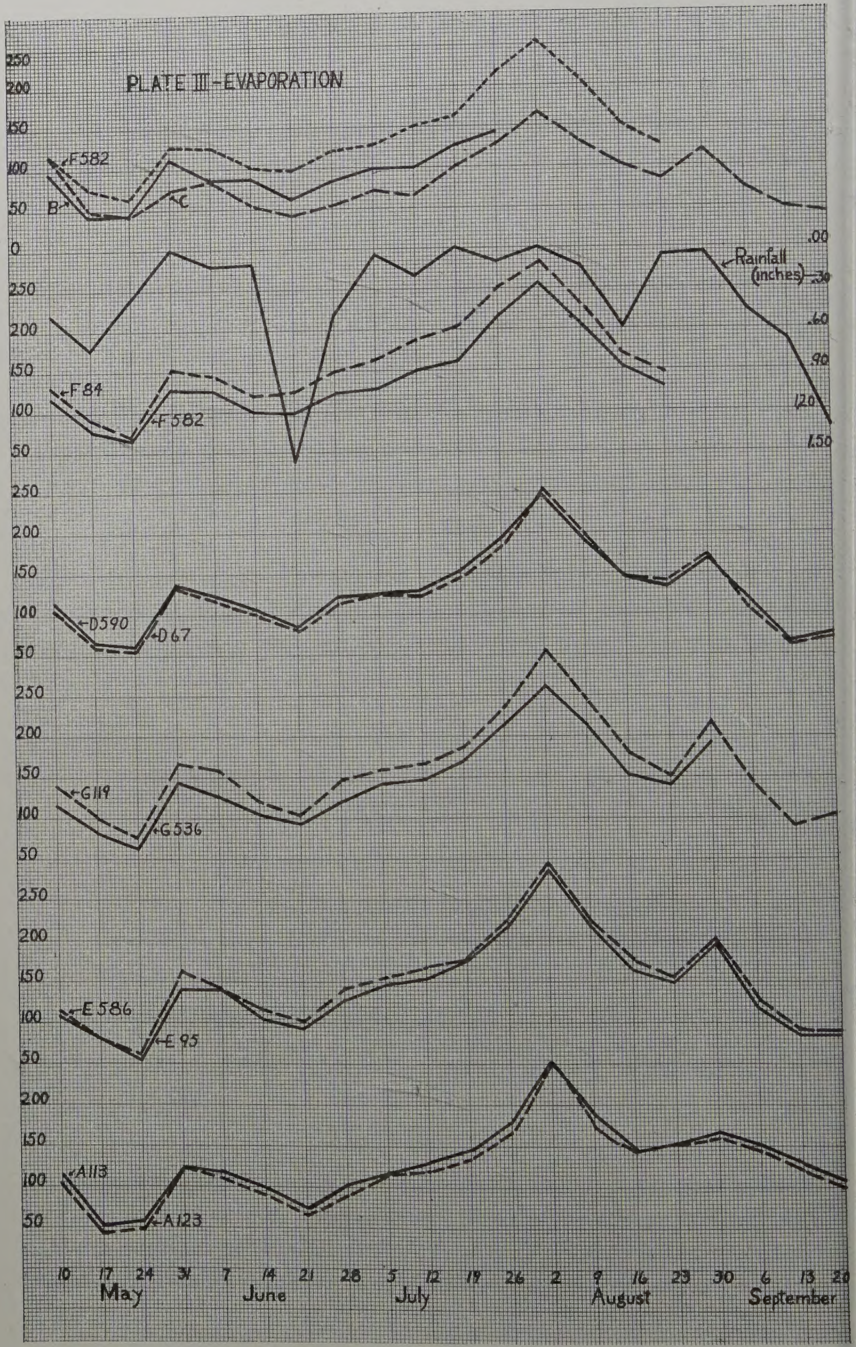


PLATE III-EVAPORATION
F582
B
C
Rainfall (inches)
F84
F582
D590
D67
G119
G536
E586
E95
A113
A123
May
June
July
August
September

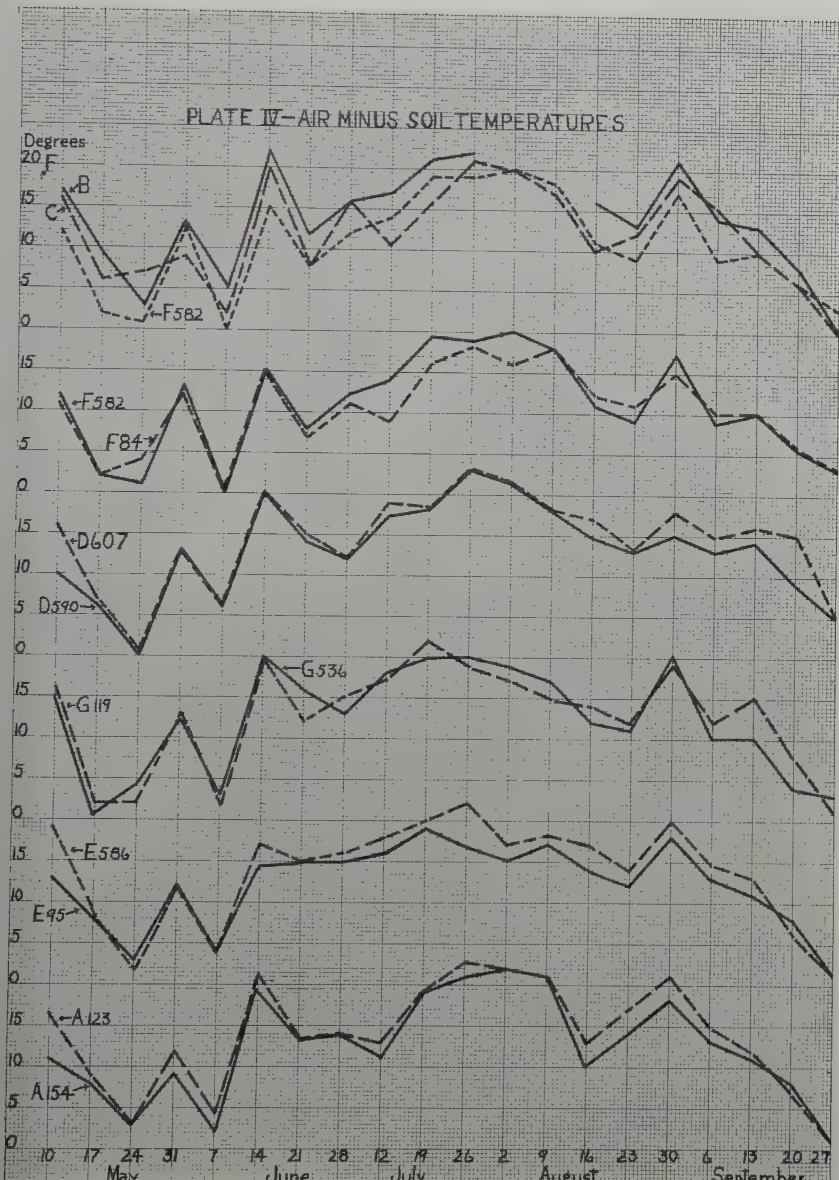


PLATE IV—AIR MINUS SOIL TEMPERATURES

seedlings were abundant (Plate IV). This means (1) that where hemlock seedlings were abundant the soils are subject to greater fluctuation with changes in air temperature than where they were inhibited by leaf litter; (2) that where hemlock seedlings are abundant the soil is warmer on hot days and therefore subject to greater drying out due to heat. This is in accord with observations on soil moisture, where it was seen that the soil contains less moisture where seedlings are growing than where leaf litter has inhibited them (Plate I). All of this means that hemlock seedlings are growing under more rigorous conditions than are present only a few feet away where leaf litter inhibits their establishment.

SEEDLING MORTALITY

Data above given have indicated that hemlock seedlings at Trevlac are growing under more rigorous conditions than are characteristic for the region as a whole. That is to say, they are growing where soil moisture is lowest, fluctuations of temperature are greatest, and in some stations where evaporation is greatest. It was therefore thought necessary to gather some accurate data on seedling mortality. Accordingly, on April 19, 1930, a number of linen tags were numbered and attached to stakes made from zinc-covered wire. These were placed beside seedlings and the exact positions and age of seedlings were recorded. On October 4, 1930, the "roll" was again taken. Results shown in Table II indicate that 88.7 per cent of the first year seedlings and 78.4 per cent of the second and third year seedlings perished. Of the entire number of seedlings tagged, 82.8 per cent perished. These results seem to be in general agreement with the conclusion that these hemlock seedlings were growing under rigorous conditions. Toumey and Neethling (8) found that hemlock seedlings are readily killed when there is a defi-

TABLE II

Summary of Seedling Mortality. Seedlings tagged April 19, 1930, and again checked on October 4, 1930

	1st Year	2d and 3d Year	Total
Tagged April 19, 1930	60	74	134
Dead October 4, 1930	53	58	111
Alive October 4, 1930	7	16	23
Per cent dead	88.3	78.4	82.8
Per cent alive	11.7	21.6	17.2

ciency of moisture in the upper stratum of soil. Further studies on seedling mortality are being carried out and data gathered over a longer period of time will be presented in a future paper.

CONCLUSIONS

1. Forest floor cover is one of the most vital factors involved in the establishment of hemlock seedlings in this study. The cover is so deep that seedlings are inhibited on the plateaus and more gentle slopes covered with the broad-leaved deciduous trees.

2. Seedlings become established on the steeper slopes wherever there is sufficient moss or other floor covering to give them lodgment, and in other areas where forest litter is not too deep.

3. Soil moisture studies show that seedlings are growing in every instance under more rigorous conditions than are present only a few feet away but where floor cover inhibited their establishment.

4. Soil temperature studies show that seedling areas are subjected to a greater amount of temperature fluctuation than neighboring areas without seedlings.

5. Evaporation studies show that areas with seedlings are sometimes subjected to greater water loss and sometimes less than neighboring areas without seedlings.

6. Wilting coefficient studies show that the wilting coefficient is higher in every case where seedlings are absent than where they are present. This is undoubtedly due to the greater humus content of the soil where floor litter is greater. Floor litter, and hence humus content, is much less in areas where seedlings are growing than where they are inhibited.

7. Wilting coefficient is higher for surface soils than for soils three and six inches deep. This is directly related to the humus content.

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STUDIES IN FOREST ECOLOGY

II. The Ecological Significance of Tsuga Canadensis in Indiana

By RAY C. FRIESNER AND J. E. POTZGER

INTRODUCTION

The hemlock, *Tsuga canadensis,* exhibits a very disjunct distribution in Ohio, Indiana, Illinois, Michigan, Wisconsin and other parts of the western and southern limits of its range. In Indiana and parts of its range farther northwest it is usually limited to steep slopes, canyon walls and deep ravines, though in some stations in Indiana, such as at Turkey Run, in Parke county, and Pine Hills, in Montgomery county, it occurs on plateau tops and stream terraces.

In Michigan it is a dominant tree in the hardwoods areas but always in more or less isolated groups or "islands," surrounded by broad-leaved trees. Occasionally it invades low ground along lakes and edges of swamps, but is more characteristically found in the upland areas. Even there it does not reproduce itself except in rare cases, and then it usually forms a dense consociation in "island-like" isolation.

Such a disconnected distribution must indicate either one or the other of two distributional alternatives. These isolated hemlock communities represent either (1) outposts of a present invasion from the east and northeast, or else (2) "rear-guards" or "relicts" of a retreating species which was pushed from the northeast during the glacial period. Distribution alone would seem to favor the latter alternative, since pioneers of an invading species usually have a more nearly continuous distribution. Physical data thus far obtained from Indiana stations also seem to favor the latter alternative, because from the standpoint of soil moisture, soil temperature and evaporation, the hemlocks have been shown (2) to be growing under conditions more rigorous than those under which its competitors, the beech and maple, are growing. That is to say, the hemlock is growing in Indiana where it is, not because its present habitats here are best suited for it, but because it can tolerate conditions less favorable to its growth much more successfully than its broad-leaved neighbors.

TABLE I

GROWTH WATER IN BEECH-MAPLE AND HEMLOCK ASSOCIATIONS, TREVLAC STATIONS, SEASON 1930

	Surface Soils		3-Inch Soils		6-Inch Soils	
Week	Hemlock	Beech-Maple	Hemlock	Beech-Maple	Hemlock	Beech-Maple
5- 3	x	x	x	x	x	x
5-10	x	x	x	x	x	x
5-17	x	x	x	x	x	x
5-24	x	x	x	x	x	x
5-31	x	x	x	x	x	x
6- 7	x	x	x	x	x	x
6-14	x	x	x	x	x	x
6-21	x	x	x	x	x	x
6-28	x	x	x	x	x	x
7- 5	x	x	x	–	x	–
7-12	–	x	–	x	–	x
7-19	–	x	–	–	–	–
7-26	–	–	–	–	–	–
8- 2	–	–	–	–	–	–
8- 9	–	x	–	–	–	–
8-16	–	x	–	–	–	x
8-23	–	–	–	–	–	–
8-30	–	–	–	–	–	–
9- 6	–	–	–	–	–	–
9-13	x	x	x	x	–	–
9-20	x	x	x	x	x	x
9-27	–	x	–	x	–	x
	Weeks No Growth Water					
	10	5	10	9	11	9
	Per Cent of Summer Without Growth Water					
	45.45	22.72	45.45	40.90	50.0	40.90
	Turkey Run (1)					
	50.0	0.0	60.0	0.0	60.0	0.0

PHYSICAL FACTORS OF ENVIRONMENT

From Table I it will be noted that, for the season of 1930, absence of growth water, *i. e.*, time when total soil moisture falls below the wilting coefficient, occurs at all soil depths for a greater percentage of the summer in hemlock associations than in beech-maple associations. The difference is greater in the surface soils than in three- and six-inch soils. Similar results, except even greater difference, were obtained by Daubenmire (1) at Turkey Run for the 1929 season. The point of importance

on the present problem is that hemlocks are growing under more rigorous conditions than the beech and maple. It may be argued that this difference is due to the hemlock and not *vice versa*. But the same conditions, and even more marked, are to be found where the seedlings are growing (2) and before they have had a chance to affect their environment. Even though it is probably true that the mature hemlocks partly account for their own more rigorous habitat, *i. e.*, their superficial root system inhibits penetration of water to greater soil depths, it is none the less certainly true that they are living in an environment more rigorous than their beech-maple neighbors.

In a previous paper (2) (Plate IV) we have shown that there is a greater difference between temperatures three inches below the surface of the soil and thirty-six inches above the soil surface where hemlock seedlings are inhibited by other factors than where they are growing. This means that the hemlock seedlings are growing in habitats subject to greater soil temperature fluctuations and hence in more rigorous habitats. It will be found that the soil temperature fluctuations (comparison of Curves B and C of Plate IV of our above cited paper (2)) of more mature hemlock stands are less than in beech-maple, but this difference is of little consequence in mature stands, because seedling establishment is of vital importance to the perpetuation of any species without vegetative means of reproduction.

Evaporation studies (2), (1) show that there is greater water loss in mature hemlock stands than in beech-maple stands. They also show that there is generally greater water loss where seedlings are growing than where the seedlings are inhibited by other environmental factors. The conclusion is again apparent that hemlocks, whether it be seedlings or mature stands, occupy more rigorous habitats than beech-maple stands.

Physiographically, hemlocks are usually limited (in Indiana) to steep slopes and canyon rims, or, if they do occasionally occur on the plateau tops or level terraces, they occur where the soil is very poor and dry.

In summarizing physical features of their environment it should be noted that from every standpoint the hemlock is growing under more rigorous environmental conditions than the beech-maple. Such facts favor the conclusion that the hemlock in Indiana is growing in isolated places, even though less favorable than where the species reaches its climax, which it can tolerate and where it can compete with its broad-leaved competitors, *i. e.*, it is all but crowded out and is making "last stand" existence in these disconnected areas.

CLIMAX CONDITIONS

According to Weaver and Clements (4), hemlock forms a part of the Lake-forest or Pinus-Tsuga formation which is the climatic climax for considerable territory in northeastern United States.

Hemlock can hardly be considered a climatic codominant with beech and maple, with which it is associated in all of its Indiana stations, because they do not belong to the same life form, *i. e.*, while hemlock is perhaps more mesophytic than any other conifer, its presence as a climatic climax indicates colder winters and shorter summers than is indicated by deciduous forests as climatic climaxes.

While hemlock is somewhat more xerophytic than beech-maple, both in regard to evaporation (Moore, *et al.* (3), Daubenmire (1), and Friesner and Potzger (2)) and in regard to soil moisture (Daubenmire (1) and Friesner and Potzger (2)), yet it more nearly approaches beech-maple in its water requirements than any other conifer does. The most obvious conclusion to be reached when due consideration is given to the environmental details of its local habitats and to the plants associated with it in each of its stations is that hemlock in Indiana represents relict communities of a former hemlock climatic climax. But it now represents only environmental climaxes in the particular stations where they are found. That is to say, the general climate of this region has changed sufficiently since the retreat of the glacier that hemlock as a climatic climax has given way to beech-maple, which is the present climatic climax of a less rigorous climate. At the same time, isolated habitats such as are now occupied by the hemlock sufficiently approach the former conditions that hemlock remains as local environmental climax communities where it can successfully compete with beech-maple.

SUMMARY

Tsuga canadensis in Indiana is considered to be a relict or local edaphic climax of a former climatic climax because

(1) Its disjunct and "island-like" distribution cannot otherwise be explained.

(2) The habitats in which it occurs are more rigorous than those of the beech-maple which is the present climatic climax association, indicating that the hemlock is maintaining itself only under those environmental conditions which are slightly less favorable than the habitats occupied by the present climax association.

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HYDROGEN-ION REACTION OF NATIVE INDIANA FERN SOILS

By Joe R. Craw

A number of studies of soil acidity in relation to plant groups and plant distribution have been made in recent years, but none of these have been carried on with the ferns of Indiana soils. The present study was made in the hope of extending such information to a wider range of soil conditions.

Trips were made at various times to different sections of the state. It was the intention to obtain as many species and samples over as wide and as representative areas of the state as possible. Three samples of soils from around the roots of each species of fern were obtained, each from a different place in the same locality. As a matter of herbarium record, fronds were pressed and labeled for each county, date, type of association and soil studied. Each soil sample was placed in a small paper sack and taken to the laboratory where the Youden hydrogen-ion concentration apparatus was used in determining the acidity or alkalinity of these soils. The e. m. f. in volts was converted into pH and this in turn was changed into terms of active acidity. These results for each separate soil sample, along with the date, place in county, the type of association and soil texture of the sample collected, were tabulated on a three-by-five inch card and filed for reference. Within a week after soils were collected they were tested. One-fifth vial of soil with three-fifths vial of water was used in the testing. After each test the electrodes and vials were thoroughly washed with distilled water. Duplicate tests of the same sample were not made, since three samples were collected in the same locality.

OBSERVATIONS

Results obtained are tabulated in Table I. Average acidity or alkalinity readings were obtained by converting the pH value of each test on the soils of each species into active acidity according to Wherry (7) and then reconverting the arithmetical average of these figures back into pH terms. This is necessary as Wherry (7) has indicated, since the pH numbers are logarithmic values. Some investigators have made the mistake of averaging pH numbers directly. This procedure in the case of *Aspidium cristatum,* for example, would have resulted in an average

TABLE I—SOIL REACTIONS OF PRESENT STUDY AND COMPARISON WITH RESULTS OF WHERRY AND ROBINOVE AND LA RUE

SPECIES	NO. OF TESTS	ACTIVE ACIDITY AND ALKALINITY: Mediacid 300	Mediacid 100	Subacid 30	Subacid 10	Minimacid 3	Minimacid 0	Minimalk. 3	Minimalk. 10	Subalk. 30	Avr. pH	Avr. Act. Ac.
		(pH) HYDROGEN-ION CONCENTRATION: 4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5		
Adiantum pedatum[1]	91C[2]	x	x	x	xx	X	xx	x			6.4	4
	30W			x	xx	X	xx	xx	x			
Aspidium cristatum	24C	xx	X	xx	xx	x	x				4.8	160
	4R				6.0	6.6					6.2	6
A. Goldianum	14C		xx	xx	x	xx	X				6.3	5
	10W				x	xx	X	x	x			
A. marginale	13C		x	xx	X	xx	xx				6.1	8
	30W		x	xx	X	xx	xx	xx	x	x		
A. noveboracense	29C	xx	xx	X	xx	xx	xx				5.8	16
	30W	x	x	X	xx	xx	xx	x	x			
A. spinulosum	36C	xx	xx	xx	X	xx					5.0	90
	20W	xx	xx	X	xx	xx	xx	xx	x			
	8R	4.2				6.4					5.3	50
A. Thelypteris	45C	xx	X	xx	xx	xx	xx	x	xx		5.6	26
	30W	x	x	X	xx	xx	xx	xx	x			
	9R	4.8							8.2		6.3	5
Asplenium acrostichoides	44C	x		xx	xx	X	xx	x			6.2	6
	10W		x	xx	X	xx	xx	xx	x			
A. angustifolium	53C	x		xx	xx	X	xx	xx			6.6	2
	10W			x	xx	X	xx	xx	x			
A. Filix-femina	73C			xx	X	xx	x	x			6.0	10
	7R				6.0				8.2		7.0	0
A. pinnatifidum	3C						x				7.0	0
A. platyneuron	28C			x	xx	X	xx	xx	x		6.6	2
	50W	X	xx	xx	xx	xx	xx	xx	xx	x		
A. Ruta-muraria	5C						X	xx	xx		7.4	2 Alk.
	?W						Circumneutral					
A. trichomanes	6C				X	x	x				6.7	1.5
Botrychium virginianum	92C			xx	xx	X	xx	xx	x		6.3	5
	?W						Circumneutral					
	9R		5.3						8.0		6.2	6

	12C			xx	X	x					6.0	10
Camptosorus rhizophyllus	20C				xx	X	xx	xx	x		7.0	0
	50W		x	xx	xx	xx	X	xx	xx	xx		
Cystopteris bulbifera	16C		x			x	xx	X	xx	x	8.2	16 Alk.
	30W			x	xx	xx	X	xx	xx	x		
	3R							7.4	8.2		7.8	6 Alk.
C. fragilis	73C		x	x	xx	X	xx	xx	xx	x	6.6	2
	30W		x	xx	X	xx	xx	xx	xx	x		
Dicksonia punctilobula	3C		xx								4.9	125
	30W	x	xx	xx	X	xx	xx	xx	x			
Onoclea sensibilis	65C	x	x	xx	xx	X	xx	x			5.3	49
	8R	4.8							8.0		6.1	8
O. Struthiopteris	6C					x	x	X			7.5	3.5 Alk.
	1R						7.3				7.3	1.5 Alk.
Ophioglossum vulgatum	10C			xx	xx	X	x				6.0	10
	?W							Minimacid				
Osmunda cinnamomea	27C	X	xx	xx	x	xx	x				4.8	160
	30W	X	xx	xx	x	x						
	5R	4.2			5.8						5.0	100
O. Claytoniana	17C			xx	xx	X	xx				6.2	6
	20W	x	xx	xx	X	xx	xx	x				
O. regalis	33C	X	xx	xx	xx	x					5.2	6.3
	30W	X	xx	xx	xx	x						
	6R	4.2				6.8					6.0	10
Pellæa atropurpurea	9C							x	x	X	8.4	25 Alk.
Phegopteris hexagonoptera	82C		xx	xx	xx	X	xx	x	x		6.3	5
	30W		x	x	X	xx	xx	xx	x			
Polypodium vulgare	10C	xx	xx	xx	X						5.6	25
	50W		x	xx	X	xx	xx	xx	xx	x		
Polystichium acrostichoides	91C		xx	xx	X	xx	xx	xx			6.4	4
	30W	x	xx	xx	X	xx	xx	xx	x			
P. acros. var. Schweinitzii	14C			x	xx	X	x	x			6.7	1.5
Pteris aquilina	30C	xx	X	xx	xx	xx	x				4.9	125
	30W	x	xx	X	xx	x						
	3R	4.6				6.8					5.4	125
Woodsia obtusa	12C					xx	X	xx	x		7.2	1 Alk.
	30W		x	xx	X	xx	xx	xx	xx	xx		
Woodwardia virginica	6C	X									4.3	300

[1]Nomenclature follows Gray's Manual.
[2]Results recorded are from Craw (C), Wherry (W) and Robinove and La Rue (R).

of pH 5.4, when the average really is 4.8 for the twenty-four tests obtained.

Robinove and La Rue (4) did some pH work on ferns in the Douglas Lake region of Michigan, using the La Motte colorimetric method. A comparison of this study with that of the writer in so far as the same species were investigated is given in Table I, where data are presented in the following order: (C) present results, (W) results obtained by Wherry and (R) results obtained by Robinove and La Rue.

Eight out of the eleven species studied by Robinove and La Rue have a broader range than those found by them when a larger number of tests are made. An example is found in *Cystopteris bulbifera,* whose range reported by Robinove and La Rue is 7.4-8.2 for three tests and that of the writer was 6.7-9.0 for sixteen tests. Again in *Aspidium cristatum,* whose range reported by Robinove and La Rue is 6.06-6.6 for four tests and the writer found it to be 4.2-7.1 for twenty-four tests. In this instance the smaller number of tests was, of course, inadequate. In some species, *e. g., Botrychium virginianum,* ten times as many tests failed materially to change the range or average.

In some species there is some indication that pH preference is different in different localities. In the case of *Asplenium Filix-femina* in Indiana, the range and average are both more acid. This may be only apparent as a result of a smaller number of samples from the Michigan distribution. In the main it does not appear possible to ascribe very definite average or range of a species on a very small number of tests. It would appear that many times true acidity is not as important a limiting factor as some other edaphic factors, such as soil moisture.

As a basis of comparison of a number of species, it is helpful to designate the frequency of samples falling in each degree of acidity by the use of different symbols. For convenience the same terms with practically the same divisions which Wherry (6) used are presented in Table I. That portion of the pH range in which less than 10 per cent of the species tested are to be found is designated by a small "x;" the most frequently observed reaction by a large "X;" and all those in between by two small "x's." Wherry's work was done by the colorimetric method. He uses the small "x" to represent those species least seen and the other two symbols as the writer uses them. The other designation of degrees of acidity written in the table as "circumneutral," "minimacid," etc., were taken from studies by Wherry (6, 7).

In comparing the work of Wherry with that of the writer a very close

parallel is revealed, despite the distance between the two regions studied. In most instances the majority of tests fall in the same portion of the range or in adjacent portions. One noticeable exception exists in the case of *Asplenium platyneuron,* which Wherry records as mediacid and which the writer found to be minimacid. Wherry also finds *Woodsia obtusa* to be more acid than the writer does. There is no striking tendency for one region to be more acid than the other, although more ferns tend to be more acid in the region studied by Wherry than do those in Indiana as a whole.

DISCUSSION

"Closely related plants may differ markedly in soil reaction preference" (Wherry (5)), or more often they may be very similar in their preference. As an example of this difference we may take *Cystopteris bulbifera,* which was found to be subalkaline, and *C. fragilis,* which is minimacid in reaction. On the other hand, one finds more closely related ferns of similar reaction, such as the species of Aspidium and/or Osmunda, which are mainly subacid, and the species of Asplenium, which are minimacid in the majority of cases.

Asplenium angustifolium, A. acrostichoides and *A. Filix-femina* belong to the same section of the genus and they all respond readily to minimacid soil and all seem to prefer the same dense wooded creek bottoms, slopes or ravines. *A. Filix-femina* shows the narrowest range in its selection of location. Often it may be found growing from the humus remains of a rotton log or decayed brush pile or at the base and shaded side of a cliff. It thrives best in a moderate amount of shade. According to Gustafson (2), humus and high acidity usually go together, and it is next to impossible to determine from field studies whether the plants grow in certain situations because of the presence of humus or of the acidity.

There were no ferns found in habitats that averaged superacid, although *Aspidium spinulosum* was sometimes found in low superacid soil; nor were any found in soils high as mediakaline except *Cystopteris bulbifera,* which bordered on low medialkaline in one sample collected.

At the extremities of acid or alkaline soil range one may notice that the plants are either few or poorly developed. A good example may be had in *Phegopteris hexagonoptera,* because where it was found in soils bordering on high subacid or minimalkaline the plants were always few

and depauperate, but where it was found to grow in minimacid soil the plants were always very vigorous in appearance. The largest and rankest patch of *P. hexagonoptera* ever noted by the writer was on a rolling hillside in an oak woods on Fort Harrison Reservation in Marion county. *Asplenium Filix-femina* and *Adiantum pedatum* were here and there scattered in the patch. The soil was a well-drained clay loam of minimacid reaction.

In this research *Aspidium cristatum, Dicksonia punctilobula* and *Woodwardia virginica* were mediacid. The first and last are primarily bog ferns, while Dicksonia is more of an upland species in Indiana. The last two may have a broader range but the small number of samples collected did not reveal it. The last grows in abundance in the tamarack bogs of the northern part of the state. *Aspidium cristatum* was found as far south as Monroe county in a sphagnum bog about eleven miles southeast of Bloomington.

A number of species of Aspidium are subacid. These include *A. spinulosum, A. marginale, A. noveboracense* and *A. Thelypteris,* along with *Ophioglossum vulgatum, Osmunda cinnamomea, O. regalis, Polypodium vulgare, Pteris aquilina, Onoclea sensibilis* and *Polystichum acrostichoides.* All of these were found to grow moderately well in mediacid and minimacid as well as in the subacid soils. Fuller (1) records *Aspidium spinulosum* as a mediacid plant. The plant was found to grow in soil that reacted from low minimacid to low superacid but the average was subacid. *Aspidium Thelypteris* shows a very broad tolerance. That is to be expected, since it may be found everywhere in wet meadows with peaty or muck soils, in bogs, in limestone basins or in sphagnum pools.

The species of Osmunda are different in habitat, yet the soil reaction is similar. *Osmunda cinnamomea* and *O. regalis* are mainly of northern swamps or bogs, yet a few plants of the latter were found in an undrained cut-over woods as far south as Pike and Jennings counties and are to be found on the moister portions of sandstone cliffs such as those occurring along White river in Martin county. Both of the above ferns have a range from neutral to mediacid. *O. Claytoniana* is more or less limited in its habitat, being found in subacid soils but more often in mediacid soils. Very few fruiting plants were found. *Polypodium vulgare* is also limited to rocky cliffs. *Pteris aquilina* is classed with *Polypodium vulgare,* few being found in sandy soils, but some were growing more rank with greater moisture.

The largest number of species fall in the minimacid group, with the first six of the following having a broad range and the others having a narrow range: *Adiantum pedatum, Asplenium platyneuron, Aspidium Goldianum, Botrychium virginianum, Cystopteris fragilis, Phegopteris hexagonopteris, Asplenium acrostichoides, A. angustifolium, A. Trichomanes, Botrychium obliquum, Polystichum acrostichoides* var. *Schweinitzii, Woodsia obtusa, Camptosorus rhizophyllus, Osmunda Claytoniana, Asplenium Ruta-muraria* and *Pellæa atropurpurea.*

Aspidium Goldianum is usually found in deep ravines or damp gorges, yet it was found in an upland deep-shaded beech-maple woods of Wayne county in greater numbers than in any other place in the state. It shows a very broad soil reaction range.

Botrychium obliquum is limited to a subacid or to high minimacid soils, while *B. virginianum* has a very broad range. So it is with *Polystichum acrostichoides* var. *Schweinitzii* and the species *P. acrostichoides.* The first of the last two is low minimacid and seems to require richer soil and a more favorable location than does *P. acrostichoides.* The Botrychium species are the unexpected ferns: never in patches but scattered where one least expects them.

Asplenium pinnatifidum is a species of neutral soil fern found at Shoals, Indiana, at Pinnacle Rock with *Polypodium vulgare, Asplenium Trichomanes, Woodsia obtusa, Dicksonia punctilobula* and *Asplenium platyneuron. Polypodium polypodioides* and *Cheilanthes tomentosa* are also at Shoals, but no testing has been done with them.

Onoclea Struthiopteris is minimalkaline in its soil reaction. It is not abundant in Indiana. Three of the samples tested were collected from specimens growing out of cultivation near Rome City and the other three were in a garden near Springport. The original plants of the latter had been brought from Michigan in 1927. There was a very close correlation between the two.

Cystopteris bulbifera and *Pellæa atropurpurea* both range from minimacid through minimalkaline, with the majority of samples collected from subalkaline soils.

From the above one sees that for the majority of Indiana ferns acid soil is required. This is not true with other groups of plants. For example, Turner (4) says that more plants grow in nearly neutral ground. He also says, as has been noted, that plants growing in soil at the edge of the soil reaction range are smaller than those growing in soil at the average of the soil reaction range for that particular species. He

has done some pH work on the Compositæ and his results show that one-fifth of the species observed tend to require acidity in their soil reaction, slightly more than one-fifth are widely tolerant of both acid and alkaline soil reaction, and the other three-fifths observed tend to require alkalinity in their soil reaction. Indiana ferns show just the opposite.

The type of ecological investigation here portrayed finds immediate application in the field of fern culture. With the knowledge of native soil types, with special reference to acidity, and of the vegetation types with which the various species are most frequently associated, greater assurance of success can be had in the cultivation of many highly desirable native species of ferns.

SUMMARY

1. The hydrogen-ion concentrations of the habitat of thirty-four species of Indiana ferns are presented.
2. At least two-thirds of Indiana ferns can tolerate a wide range of soil reactions.
3. The majority of Indiana ferns grow in acid soils.
4. *Cystopteris bulbifera* and *C. fragilis* are closely related species, yet they differ markedly in the soil reactions of their habitats.
5. No ferns were found to have an average of superacid or medialkaline soil reaction.
6. Fern plants growing in soils at the extremities of acid or alkaline soil range are few and dwarfed.
7. Most of the data here presented for Indiana agree with the results of Wherry, and Robinove and La Rue, whose work was done in the East and Michigan, respectively.

The author wishes to recognize Dr. R. C. Friesner, of Butler University, for helpful interest and criticism and the use of laboratory apparatus; Charles Deam, State Research Forester, for citing places rich in fern life; and Dr. Stanley A. Cain, who suggested this problem and under whose direction this investigation was carried out.

LOCALITIES

A list of the species and the various counties in which they were collected are given below as a contribution to Indiana biological survey. Specimens used in this work have been deposited in the Butler University herbarium.

Adiantum pedatum—Soil samples were taken from: Montgomery, Pike, Vigo, Whitley, Steuben, Boone, Bartholomew, Martin, Delaware, Randolph, Lawrence, Marion, Washington, Henry, Jefferson, Wells, Putnam, Wayne, Ripley, Floyd, Monroe, Brown, Clay, Owen, Posey, Sullivan, Grant, Morgan, Parke and Lagrange.

Aspidium cristatum—Soil samples were taken from: Whitley, Howard, Wells, Allen, St. Joseph, Dekalb and Grant. Specimens without soil samples were also taken from Monroe.

Aspidium Goldianum—Soil samples were taken from: Brown, Parke, Delaware and Wayne.

Aspidium marginale—Soil samples were taken from: Martin, Brown, Morgan and Parke.

Aspidium noveboracense—Soil samples were taken from: St. Joseph, Jennings, Morgan, Bartholomew, Brown, Steuben, Elkhart, Wayne, Parke and Lagrange.

Aspidium spinulosum—Soil samples were taken from: Allen, Whitley, Elkhart, Parke, Delaware, Grant, Steuben, Marion, Wayne, Randolph, St. Joseph and Dekalb.

Aspidium spinulosum intermedium—Specimens without soil samples were collected in Howard.

Aspidium Thelypteris—Soil samples were taken from: Montgomery, Kosciusko, Noble, Howard, Parke, Dekalb, Whitley, Marion, Steuben, Brown, Allen, Fulton, Wells and Elkhart.

Asplenium acrostichoides—Soil samples were taken from: Marion, Morgan, Brown, Wayne, Clay, Martin, Bartholomew, Steuben, Floyd, Sullivan, Henry, Randolph, Boone, Delaware and Parke.

Asplenium angustifolium—Soil samples were taken from: Sullivan, Boone, Martin, Jefferson, Vigo, Pike, Randolph, Henry, Brown, Floyd, Parke, Monroe, Morgan, Montgomery, Owen, Delaware, Marion and Wayne.

Asplenium Filix-femina—Soil samples were taken from: Lagrange, Martin, Delaware, Parke, Morgan, Brown, Henry, Randolph, Boone, Jennings, Marion, Wayne, Pike, Vigo, Clay, Putnam, Sulli-

van, Allen, Martin, Whitley, St. Joseph, Bartholomew, Steuben and Elkhart.

Asplenium pinnatifidum—Specimens without soil samples were taken in Martin.

Asplenium platyneuron—Soil samples were taken from: Martin, Lawrence, Posey, Washington, Orange, Vigo, Parke, Morgan and Brown.

Asplenium Ruta-muraria—Soil samples were taken from Jefferson.

Asplenium Trichomanes—Soil samples were taken from Martin. Specimens were collected in Parke.

Botrychium virginianum—Soil samples were taken from: Delaware, Brown, Bartholomew, Martin, Jennings, Scott, Henry, Boone, Vigo, Wayne, Cass, Steuben, Montgomery, Washington, Monroe, Marion, Jefferson, Pike, Knox, Putnam, Sullivan, Owen, Lagrange, Whitley, Grant, Parke, Randolph and Morgan.

Botrychium obliquum—Soil samples were taken from: Wayne, Marion and Elkhart.

Botrychium obliquum disectum—Specimens without soil samples were taken from Wayne.

Camptosorus rhizophyllus—Soil samples were taken from: Martin, Brown, Jefferson, Parke, Floyd, Wayne and Owen.

Cheilanthes tomentosa—Specimens without soil samples were taken from Martin.

Cystopteris bulbifera—Soil samples were taken from: Wayne, Parke, Owen and Jefferson. Specimens without soil samples were taken from Lawrence.

Cystopteris fragilis—Soil samples were taken from: Sullivan, Vigo, Wayne, Monroe, Brown, Delaware, Marion, Pike, Scott, Henry, Montgomery, Parke, Floyd, St. Joseph, Grant, Hendricks, Clay, Knox, Boone, Wayne, Morgan and Elkhart.

Dicksonia punctilobula—Soil samples were taken from Parke. Specimens without soil samples were taken from Martin.

Onoclea sensibilis—Soil samples were taken from: Hendricks, Henry, Knox, Marion, Brown, Noble, Morgan, Parke, Delaware, St. Joseph, Vigo, Pike, Wayne, Jennings, Ripley, Kosciusko, Whitley, Hamilton, Steuben, Elkhart, Crawford, Dekalb, Fulton and Allen.

Onoclea Struthiopteris—Soil samples were taken from Noble. Other specimens and soil samples were taken from a garden in Henry near Springport.

Ophioglossum vulgatum—Soil samples were taken from: Marion and Morgan.

Osmunda cinnamomea—Soil samples were taken from: St. Joseph, Grant, Fulton, Howard, Whitley, Dekalb, Allen, Cass and Lagrange. Specimens without soil samples were collected from Monroe.

Osmunda Claytoniana—Soil samples were taken from: Morgan, Steuben, Brown and Parke.

Osmunda regalis—Soil samples were taken from: Grant, Whitley, St. Joseph, Jennings, Steuben, Kosciusko, Pike, Allen, Fulton and Howard. Specimens without soil samples were collected from Monroe.

Pellœa atropurpurea—Soil samples were taken from Jefferson.

Phegopteris hexagonoptera—Soil samples were taken from: Owen, Wayne, Delaware, Boone, Brown, Morgan, Whitley, Sullivan, Putnam, Scott, Ripley, Steuben, Gibson, Clay, Knox, Bartholomew, Pike, Monroe, Lawrence, Martin, Parke, Randolph, Henry, Jefferson, Marion, Jennings, Floyd and Crawford.

Polypodium vulgare—Soil samples were taken from: Martin, Parke and Brown.

Polypodium polypodioides—Specimens without soil samples were taken from Martin.

Polystichium acrostichoides—Soil samples were taken from: Parke, Morgan, Posey, Lawrence, Brown, Washington, Randolph, Monroe, Jefferson, Marion, Scott, Jennings, Ripley, Montgomery, Bartholomew, Boone, Lagrange, Vigo, Knox, Hendricks, Martin, St. Joseph, Elkhart, Clay, Owen, Wayne, Putnam, Sullivan and Steuben.

Polystichum acrostichoides Schweinitzii—Soil samples were taken from: Morgan, Floyd, Brown, Lawrence and Parke.

Pteris aquilina—Soil samples were taken from: Fulton, Brown, Lagrange, Marshall, Morgan, Dekalb, Cass, Steuben, Knox and St. Joseph. Specimens without soil samples were also taken from Martin.

Woodsia obtusa—Soil samples were taken from: Morgan, Martin and Lawrence.

Woodwardia virginica—Soil samples were taken from: Noble and Kosciusko.

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BOOK REVIEWS

NATURAL HISTORY

Nature lovers and conservationists will find a very interesting and instructive contribution in Dr. Simpson's recent book.[1] The chapter on vegetation of Florida gives the author's interpretation of the origin of the local flora, and this, together with the chapter on weeds and plant tramps, will be of interest to more technical students of plant geography as well as the layman. His consideration of nomenclature will find many sympathetic readers but is rather unfair to the scientific taxonomist. His conception of the origin of epiphytic plants is interesting. Teleological concepts are naïve in places but the factual content will interest the technical botanist even though he may not care for the teleology. The chapter on evolution of leaves is ingenious, interesting and quite suggestive. Every traveler planning a trip through Florida will do well to read and have with him this book, if he would have an intelligent appreciation of Nature's vast labyrinth as it occurs in the southern half of the state.—R. C. F.

CACTI

Seventy-five species are described in nontechnical yet scientifically accurate language in the latest book to appear dealing with Cacti.[2] Details for identification, habitat and culture are given for each species. Data on geographic distribution for each species and maps showing ranges of a number of the more common forms make the book a valuable contribution to plant geography. All who are lovers of home gardens and care to have Cacti in them will find the book a valuable addition to their library of garden books. The style is excellent, casting the spell of the Southwest upon the reader—R. C. F.

GENERAL BOTANY

A number of excellent books in the field of general botany have recently appeared. Professor Seward[3] has filled a long-felt need in writing of plants and their life processes for the layman with little or no knowledge of botany. The language is free from unnecessary tech-

[1]Simpson, Charles T. Florida wild life. pp. XII + 199. pl. 110. New York: Macmillan Co. 1932.

[2]Thornber, John James, and Frances Bonker. The fantastic clan. pp. XIV + 194. pl. 54. New York: Macmillan Co. 1932.

[3]Seward, A. C. Plants: What they are and what they do. pp. XII + 141. fig. 31. Cambridge: University Press. New York: Macmillan Co. 1932.

nical terms and will do much to win the appreciation of the public for the labor and service of science. Among the chapters is to be found a consideration of the difference between plants and animals, response to stimuli, the relation of green plants to other organisms, the construction of foods and the role of lower forms of life in the economy of Nature.

Dr. R. E. Torrey[4] is the author of the first new book on general botany for the college student to come to our attention this year. The effort is to some degree a new departure for a beginning textbook. The factual content throughout is presented not for its own sake but as the elements out of which theories and broader generalizations are built. The work, therefore, has a strong dynamic, philosophic and historic trend and should do much to stimulate clear thinking among students. Part I considers the structure and classification of seed plants; Part II deals with anatomy and physiology of seed plants and Part III with the evolution of the plant kingdom. The order of treatment is not orthodox and will likely necessitate much rearrangement of laboratory material for most teachers who adopt the book as a text, but the work as a whole is so vitalizing and stimulating that it is well worthy of serious consideration for use as a textbook for beginning classes.

Dr. Mottier[5] has written a new book in his "Textbook of Botany for College Students." It is not merely a revision of his earlier work, but contains a number of chapters of new material not covered in the earlier edition. A chapter on Mendelism and one on geographic distribution are among the new material. In this book, as well as the earlier, life processes and biological principles are presented not as ends in themselves but as parts of organisms which illustrate them. The entire spirit of the book is strongly dynamic, presenting every organism as a living, functioning entity. The phylogenetic sequence of organisms is so bound together by consideration of the life processes which they illustrate that the student unconsciously becomes "organism conscious" and "phylogenetically conscious," and botany becomes to him a unified science rather than a collection of disconnected principles and isolated organisms.

The third new book in the field of general college botany to make its appearance is that written by Dr. Eyster.[6] Part I deals with general principles and life processes, with a brief survey of the plant kingdom

[4]Torrey, R. E. General Botany for colleges. pp. XXII + 449. fig. 251. New York: Century Co. 1932.

[5]Mottier, David M. A textbook of botany for college students. pp. XIII + 601. fig. 542. Philadelphia: P. Blakeston's Son & Co. 1932.

[6]Eyster, William H. College botany. pp. XVI + 695. fig. 565. New York: Ray Long and Richard R. Smith, Inc. 1932.

in the second chapter in order that the life processes to be considered may include the entire range of the plant kingdom. Part II deals with the morphology and life history of organisms illustrating the phylogenetic sequence. The language is clear, the terms are well defined and the figures are largely original, unusually well drawn and well reproduced. The chief criticism offered by the reviewer is that many important biological concepts, such, for example, as alternation of generations, are presented apart from the organisms which illustrate them so that the principles stand out as ends in themselves rather than vital parts of living, functioning organisms. Paleontological and phylogenetic relationships are well expressed. Among the noteworthy features is an excellent consideration of the phylogeny and taxonomy of the seed plants and a glossary of terms at the end of the book. The books represent an excellent piece of workmanship from every standpoint.—R. C. F.

RECENT ADVANCES IN BOTANY

The second volume of the "Recent Advances"[7] series has recently appeared. This volume, written by the same author, covers certain phases of botany in which there is insufficient material to warrant separate volumes, leaving cytological and genetical aspects to be treated in subsequent volumes. The opening chapter deals with anatomical concepts, such as the relation of size to form, the phyllode theory, significance of cotyledons and carpel polymorphism. Chapter II deals with paleobotany, presenting not only advances in technique but also much material of special value to the student of plant geography. Taxonomy is treated in the third chapter especially from the standpoint of species concept and the relation of ecology and genetics to it. Then follow several chapters dealing with advances in morphology, reproduction and life histories of fungi and algæ and a special chapter on mycorrhiza. A final chapter deals with the nature and behavior of plant viruses.

The authors and publishers of this series of volumes are to be commended both for the idea and the excellency of the numbers already published. They have made a significant contribution to the teacher and research worker so burdened with routine that the reading and proper orientation of the periodical literature in more than his own small sphere of primary interest is impossible. No botanist wishing to keep abreast of the field dare go without reading these volumes.—R. C. F.

[7] Barton-Wright, E. C. Recent advances in botany. pp. VIII + 287. fig. 60. Philadelphia: P. Blakeston's Son & Co. 1932.